DOCUMENT RESUME

ED 477 025 IR 021 753

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TITLE	Designing High Quality Learning Environments: Reflections on Some Successes and Failures.
PUB DATE	2002-06-00
NOTE	8p.; In: ED-MEDIA 2002 World Conference on Educational Multimedia, Hypermedia & Telecommunications. Proceedings (14th, Denver, Colorado, June 24-29, 2002); see IR 021 687.
AVAILABLE FROM	Association for the Advancement of Computing in Education (AACE), P.O. Box 3728, Norfolk, VA 23514. Tel: 757-623-7588; e-mail: info@aace.org; Web site: http://www.aace.org/DL/.
PUB TYPE	Reports - Evaluative (142) -- Speeches/Meeting Papers (150)
EDRS PRICE	EDRS Price MF01/PC01 Plus Postage.
DESCRIPTORS	Computer Assisted Instruction; *Computer Software Development; *Computer Software Evaluation; Computer Software Selection; *Design Preferences; *Distance Education; Educational Media; *Educational Technology; Instructional Design; *Instructional Materials; Student Participation

ABSTRACT

Over the past decade, there have been many changes in the tools used to design, the ways information can be represented and the underpinning theories which drive educational experiences. This paper focuses on several examples of software design that have been pedagogically successful and have demonstrated what is possible in software design and online learning. Contrasts are made with some examples of the current push into e-learning and how best to structure learning environments to ensure student participation and high quality learning outcomes especially when students come from differing backgrounds and cultural traditions. A summary of key projects and their focus is presented at the end of the paper. (Contains 15 references and 2 figures.) (Author)

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Designing high quality learning environments: Reflections on some successes and failures

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Over the past decade, there have been many changes in the tools we use to design, the ways information can be represented and the underpinning theories which drive educational experiences. This presentation will focus on several examples of software design that have been pedagogically successful and have demonstrated what is possible in software design and online learning. Contrasts will be made with some examples of the current push into e-learning and how best to structure learning environments to ensure student participation and high quality learning outcomes especially when students come from differing backgrounds and cultural traditions.

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"A poor tradesman blames his tools"

Over the past decade there have been several major developments which have helped the growth of interactive multimedia and more recently the concept of e-learning. The task for designers has been challenging and this paper reviews several projects, many of which broke new ground and won international awards. Along the way the reality of creating innovative products which represent good practice and seek to model modern educational principles has been driven by several factors not the least being the tools which have been used and the visual representations of the knowledge domain of each product. This paper will describe several projects and critique their design ideas and their execution.

Significant efforts have been made to develop and implement alternative frameworks for learning often based on a class of theories collectively referred to as constructivism. Fundamentally, constructivism asserts that we learn through a continual process of constructing, interpreting, and modifying our own representations of reality based on our own experiences. Indeed many books enumerate a long list of ideas about how these principles might be applied to the design of learning environments, but how to place the ideas strategically into the learning experience is often omitted (see for example, Khan, 2001; and Mills, Lawless and Merrill, 2001). Often the advice is very broad and covers all aspects of pedagogical design from methods to integrate new technologies to potential assessment strategies. The integration of technologies, which may allow the representation of ideas in many different media forms, provide opportunities for the designer or instructor to customise instruction and place learners in open-ended, student-centred, rich tasks.

This paper explores what has been effective and what, while superficially might be seen as an effective product or set of ideas, might not have been as successful as first expected. It will generalise some of the lessons that might be drawn from the decade of effort to ensure that the learning environments:

1. fostered judgement and learner responsibility.
2. supported critical inquiry and creative approaches to problem-solving
3. created engagement through the effective combination of learning task, visual representation and authentic assessment of the product goals.

Principles assumptions and quality

Like past revolutions in education, e-learning will go the way of previous technologies unless there are changes to the design framework used as the starting point. Savery & Duffy (1995) described four principles that should be applied to modern technology-based learning environments based on constructivist views. These were:

1. Learning is **an active and engaged process**. "Learners are actively engaged in working at tasks and activities that are authentic to the environment in which they would be used." (Savery & Duffy, 1995, p.37).

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2. Learning is **a process of constructing knowledge**. Learners need structures and challenges from which to develop their understanding of ideas and of the world.
3. Learners **function at a metacognitive level**. Learning is focused on thinking skills rather than working on the "right answer the teacher wants". Students generate their own strategies for defining the problem and working out a solution. Student can gain wisdom through reflection.
4. Learning involves "**social negotiation**". Students are able to challenge their thoughts, beliefs, perceptions and existing knowledge by collaborating with other students thus assisting their cognitive development process.

In a recent paper, David Boud and Mike Prosser (2002) have also attempted to specify the characteristics of high quality learning outcomes. They suggest that the four major areas of concentration in a high-quality learning environment should be:

1. How do learning activities support **learner engagement**? (This reasons for the learner wishing to become involved with the learning tasks and the way the tasks require them to reflect or employ their previous interests and understandings)
2. How does this learning activity **acknowledge the learning context**? (In the case of e-learning there are unique characteristics such as the unique position of the learner in a real context and how the assessment matches the real world skills that are seen as easily transferred from the learning context to professional practice)
3. How does the learning activity seek to **challenge learners**? (Novices need supportive structures, experts require information to fill in the missing blanks in an existing knowledge structure, too much ambiguity can turn a student away, too little and they become bored. Students might need support to extend the information provided as part of a problem-solving scenario)
4. How does the learning activity **provide practice**? (As with most effective learning contexts the matches between assessment, learning tasks, and the transfer tasks might align and model performance. To ensure that it occurs, the feedback must support the ongoing development of the learning)

In addition, in the e-learning context the choices of technology infrastructure and its deployment are crucial to support the effective learning outcomes. So the above lists describe the goals for constructivist design and high quality outcomes, but the choice of tools and the range of pedagogical options that the tools themselves either constrain or facilitate will also contribute to the learning outcomes. David Jonassen (2000) has provided recent guidance about the importance of the design of learning tasks by suggesting a range of problem types that vary in the degree of structure and the linkage they have to authentic real world tasks. Providing structure and support for the more ill-structured task is the real challenge for the designer working in a constructivist framework.

Design intentions for digital media

With an understanding of the shortcomings of much of the commercially generated available learning packages, a combination of ideas taken from constructivist learning environments, situated learning and problem-based learning in rich information landscapes can be used to form the basis for effective design. Hedberg et al (1994) proposed that learning outcomes in digital environments depend on starting points such as; the learning environment; the learner's view of the purpose of the task; and the motivation of the learner.

The process of learning involves the construction of meanings by the learner from what is said, demonstrated or experienced. Thus the role of the teacher is one of facilitating the development of understanding by selecting appropriate experiences and then allowing students to reflect on these experiences. Often constructivist learning situations *suddenly* throw students on their own management resources and many fend poorly in the high cognitive complexity of the learning environment. Cognitive support tools and the explicit acknowledgment of the double agenda of metacognitive self-management and learning can help. The scaffolding and coaching of the cognitive apprenticeship model offers another solution, a strategy which many design teams have explored with a great deal of success.

Several multimedia design models have been developed which illustrate the combination of complex learning environments and which also give students their own real control over their learning environment. If one of the primary goals of e-learning is to stimulate active involvement, then educators and instructional designers need to better understand the symbiosis between the visual interface and the design of the learning tasks in promoting and sustaining learner engagement. Engaged learners are intrinsically motivated to perform. They direct their

efforts to understanding the tasks and challenges in a learning context; and they strive to construct knowledge and derive meaning from their prior experience and available resources. Well designed visual interfaces can help stimulate learner engagement or, conversely, disengage learners if they are poorly designed. Poor design can place high cognitive demands upon the learner that can reduce interest and divert attention away from the primary learning tasks. While not described in detail here, the combination of visual clarity of knowledge representation and manipulation and the sensitivity to outcomes of the learning task is which create challenge and engagement is a measure of the design success (Metros and Hedberg, 2002).

Instructional designers continue to wrestle with the challenge of affording a new generation of visually savvy learners with engaging online experiences. In her seminal book *Computers as Theatre,* Laurel (1993) suggested ways to use the notion of theatre, not simply as a metaphor, but as a way to conceptualize human-computer interactions. Laurel defines this type of engagement as, "what happens when we are able to give ourselves over to a representational action, comfortably and ambiguously. We gain a plethora of new possibilities for action and a kind of emotional guarantee" (p115). What Laurel is referring to is *Flow State*. Csikszentmihalyi (1996) coined the term to describe the state of total engagement. Users attain *Flow State* when they have no conscious awareness of the passage of time. *Flow State* occurs when users enjoy a sense of playfulness, a feeling of being in control, a period of concentration when attention is highly focused, an interlude of enjoyment of an activity for its own sake, a distorted sense of time, and a rewarding match between the challenge at hand and one's personal skills. The emphasis on motivating tasks situated within well-designed and engaging interactions provides the instructional designer greater surety that the final experience will be effective.

Creating a framework for review

Step 1: Information Design and Project Space Definition

At the beginning of any project it is necessary to compile information on learners' needs and describe the parameters of the project space. The purpose of this initial stage is to begin a holistic structuring of the information and to model it so that it will eventually form the basis of an organizing visual metaphor. Isolating the key attributes within a learning experience is not trivial. Three questions need to be answered by the client and designers.

1. *What is the topic (content) of this project*?
2. *Who are the intended users of this knowledge domain*? The content might be the same for different groups, but learners may want to "view, use or manipulate" the content in different ways.
3. *Why is this project(course) being undertaken or developed*? The client's original stated objective almost always needs revisions to better identify and describe the underlying purpose.

Step 2: Interaction Design

Effective interaction design that matches users' cognitive expectations ensures they are motivated and engaged. Simply the use of interactive technologies does not necessarily ensure that meaningful interactions will occur, rather The challenge is to create interactions that are easily manipulated at the users' technology skill level. Norman (1988) provides guidelines for constructing interactions.

1. *Visibility*: The user can tell the state of the device and the alternatives for action through observation.
2. *An effective conceptual model*: There should be consistency in how program functions "work" leading to a coherent conceptual user model.
3. *Effective mapping*: There are clear relationships between actions and results, controls and their effects, and between system state and what is visible.
4. *Feedback*: There must be continuous feedback about the results of actions. Novice designers often fail to realize that almost every action creates some perturbation. For feedback to be effective, designers should employ a variety of feedback that link to specific learning outcomes.

In addition to Norman's guidelines, there are alternative techniques for reducing the cognitive load on a learner's working memory to enhance interaction design.

1. *Use visual conventions borrowed from the real world*.
2. *Apply consistent visual metaphors*.
3. *Recognize the role of the learner as actor*. The user is participating in a dialogue that is unfolding, often in real-time (Laurel, 1993; Hedberg & Sims, 2001).

In several products, we provide access to the data in the same way as individuals would access, manipulate and explore resources in the real world. While there still must be supportive scaffolds and structures, the choices the learners make under this model are similar to those they make as "experts" in a knowledge domain. The only difference is that the tasks have supportive elements that describe decisions in context (Lave & Wenger, 1991). Visual metaphors and information structures must provide information-rich presentations, especially when the structures are extensible and can be unfolded, as the learners need more or less support and scaffolding to complete their chosen learning tasks.

Step 3: Presentation and Interface Design

The third step transforms the design concepts derived in the first two steps into a visual presentation structure, which represents concepts, conveying order, classifying information, clarifying meaning, directing focus, stimulating interest, facilitating interactions, confirming choices, supporting recall, directing navigation, creating ambience and otherwise engaging the learner. In many products, we chose visual metaphors of commonly-used places to serve as the context in which decisions about the learning tasks take place. Thus we used a field research centre for the ecological set of problems, a classroom with small groups placed around it to model groupwork for teaching K-2 mathematics.

Issues that have influenced the journey

While the above design intentions and process has been following to a greater or lesser extent, the following key aspects that have influenced the "judged effectiveness" of each project and have formed the basis of comparison:

- *Technological advances* — major advances in the past ten years have made a difference. Especially the advent of QuickTime in late 1991, the widespread availability of World Wide Web, and the use of browsers to drive cross platform products from 1994.
- *Visual Design* — mirroring the technology developments, several graphical design tools have improved and developed in the decade. Photoshop enables visual design overlays with their "layers"
- *Design of Learning Tasks* — the visual representation and the tools for constructing environments have been instrumental in achieving the growth in complex learning tasks and how they have been implemented in software.
- *Authentic assessment options* — as digital media became easier to integrate within products, the possibilities of presenting authentic environments where the assessment tasks were realistic and authentic became greater.
- *Clarity of team goals and ease of operation* — there are several options about how a team functions, as projects grew bigger the size of the team also increased but the relationships between client and designers, and the others contributing to the final product can have a critical bearing on the clarity of the representation of the knowledge space and the symbiotic relationship between the learning task and the visual representation of the task through the interface.
- *Degree of control of design team versus client demands* for particular outcomes. The client can support options to ensure new and creative implementation of their ideas. If this occurs then the project can push the boundaries, create new representations and more challenging tasks.
- *Implementation support in the field* — a project may have the best of intentions but it may not have support which makes it viable to generate high use by the intended audience. Also the increasing combination of CD-ROMs and web sites designed to maximise the feedback and interactivity can ensure that the products have the equivalent of "after sales service".

Examples of effective Symbiosis

The complete list of examples is provided at http://www.emlab.uow.edu.au/. However simple illustrations of the review can be drawn from the CD entitled "*123 Count with me*," which illustrates the application of the model (Figure 1). The CD introduces basic mathemtical concepts to K-2 teachers and shows them how they might use an innovative instructional strategy to group students and introduce basic mathematical concepts. If a comparison is made between the two different approaches to a similar task (Figures 1 and 2), it can be seen that the poor representation of Figure 2 (and the fact that it varies with cursor movement) can be very difficult for an audience which does not hold sophisticated interface conventions. The comparison can be made over a range of factors which are outlined in the next section. (Other examples will be demonstrated in the presentation. These will be based on several products, including: *Stagestruck, Exploring the Nardoo, aspire, Pilotage* and *Count me in too*.)

Figure 1. Modelling the information and the message in "123 Count with me" through a spatial metaphor familiar to the intended audience

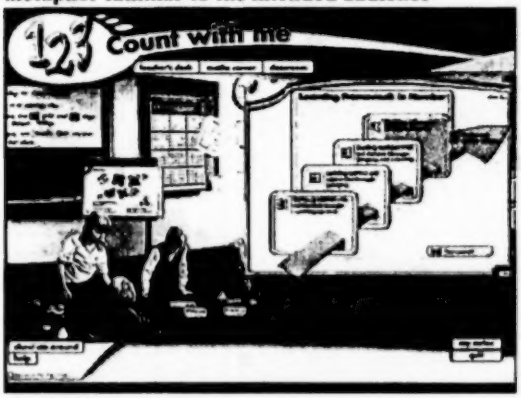
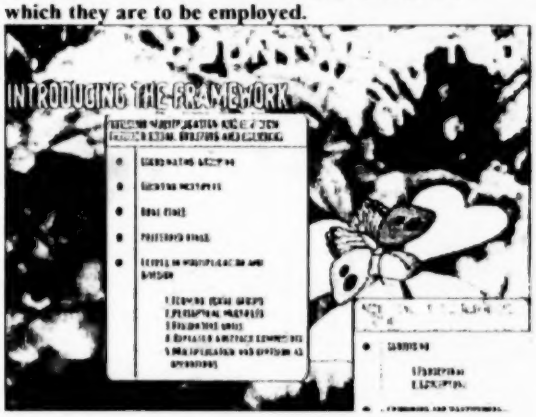


Figure 2. An alternative implementation of similar ideas without solid links to the environment in which they are to be employed.



Ensuring successful outcomes

There are many factors that might be judged as creating successes and when they are lacking producing less successful products. However in this paper, I will concentrate on a few:

Implementing the design concept. An idea at the concept stage may not necessarily translate into a good visual representation as the project develops. For instance, in developing materials to teach teachers how to implement a math program then the visual representation of those ideas has to correspond with the original concepts and intentions. Comparing the two figures (1 and 2) above which illustrate two forms of the same idea. Figure 1 was judged more comprehensible by the client. While in Figure 1, the major focus was to introduce mathematical understandings to an audience of remotely located teachers, for Figure 2, the emphasis was on explaining the nature of the mathematical framework and the visual elements became more focussed on decoration rather than functionality.

Representing information so that it can be accessed and manipulated. In the same example, in providing a list of options the use of the directory metaphor has been employed. In the early stage of design of *123 count with me*, we identified three organizing areas in which the related elements of information could be clustered and which provide meaningful structures for a teacher using a classroom metaphor.

Implementing constructive and problem-based activities. In many learning environments, learners can manipulate the elements which form the basis of their construction. Again in the above example, several capabilities have been provided which simplify some of the teacher/user tasks. There is a subtlety and a strategy to the design of activities which will lead to active use and engagement. The choice of problem (Jonassen, 2000) and the subtle development of activities that move from social to task focus suggest the direction of challenge for the designer. Jonassen (2000) has demonstrated how his initial theory of problem design can be translated into challenging tasks. Often this will mean that initially task a designed as series of discreet assignments, a rethink can create a series of linked tasks and challenges, and when these are woven into an ongoing scenario in which the student builds their skills as the go through the activities sequence then powerful learning outcomes can be produced.

Conclusion

Effective e-learning environments build upon solid foundations of learner needs and outcomes, metaphorically crafted cognitive processes, and instructional strategies communicated through effective visual interfaces that intrigue, challenge and engage the learner. Crafting of such projects requires an approach in which the instructional designer, technologist, graphic designer, educator and student collaborate to ensure that the end result is usable, functional and visually communicative and attractive. This can be accomplished by employing

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reasonable yet innovative conventions; such as organizing visual metaphors that scaffold access to the underpinning knowledge; choosing tasks that support the desired level of challenge and engagement. As interactive technologies become the staple communication vehicle for virtual worlds, effective interactive instructional design based on constructivist principles will ensure that the learner's focus on the learning task rather than simply operating the software. The choice of authoring tools can also greatly affect the way information may be structured and manipulated. Popular authoring tools may actually reduce the interactivity and information representations that are possible (Hedberg & Sims, 2001). Achieving success means that there is coherence between task, its visual representation and the project functionality. So the choice of tool, the selection of task and the importance of an engaging learning experience need to be undertaken with insight. And for e-learning, while some tools might facilitate the physical process of putting educational materials online and creating learner access, they may also never address the educational outcomes for high quality learning.

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Summary of key projects and their focus

123 – Count me in Too Credentialing Package (in production) Client: NSW Department of Education and Training, Curriculum Support Directorate.

Following the success of the earlier package, this package is being designed to assess the performance of those teachers who are seeking accreditation as "experts" in the use and application of the 123 K-2 mathematics program. It consists of a CD-ROM and links with a central site that will mark each authentic assessment.

123 - Count with Me (2002) Client: NSW Department of Education and Training, Curriculum Directorate.

The primary focus of the '123 Count With Me' CD-ROM project is to provide professional development to primary school teachers in small, remote schools who do not have easy access to district consultancy support. The project is based on the content of the Curriculum program "Count Me in Too", which is a numeracy program aimed at K-2. This numeracy program increases teachers' understandings about how children can be assisted to progress through the early components of the Mathematics syllabus in relation to Number.

K-6 Creative Arts Syllabus Professional Development (2002). Client: NSW Department of Education and Training, Curriculum Directorate

The aim of this project is to provide a tool for teachers that helps them to implement the Creative Arts K-6 syllabus. The CD-ROM illustrates and explicates the syllabus and CSD resources, demonstrating the syllabus in practice. Practice and methodology is shown through a range of visual and text modes. The CD-ROM allows teachers to explore all aspects of the syllabus, in a way that suits them as adult learners. The structure and content contained within the resource will support investigation by individual teachers working alone or in groups working under the guidance of a curriculum officer.

Pilotage Courseware (2001). Client: IMPART Corporation, RAN and SAF

The Royal Singapore Navy and Royal Australian Navy requested the submission of a creative solution to increase the level of success that trainee Officers of the Watch currently enjoy and the level of access they have to a flexible, practical training environment. Trainee Officers are provided with the basic background theory of pilotage, and a means of practicing the application of this knowledge and developing associated skills. This occurs in a simulated 'real life' environment that is consistent with being a pilot on a combat ship. In effect this provides an effective training environment whilst avoiding the usual risks and costs associated with conducting such practice in the real world.

aspire –Olympic Resource Kit for Australian Schools (1999). Clients: SOCOG; AOC; Collaborators: Dept of Education and Training; Curriculum Corporation

aspire: an educational kit developed for the 2000 Olympic Games comprises, a CD-ROM, booklet, posters and video and was distributed to schools Australia wide in 1999. The aim of the kit is to foster enthusiastic engagement in the Olympic experience and a belief in the Olympic spirit. It sought to raise interest in the Sydney 2000 Olympic Games and promote the richness and cultural diversity of Australian life and national identity. The target audience was wide K-12.

StageStruck (1998). Collaborators: The National Institute of Dramatic Art, The Australian Ballet, Opera Australia and The Sydney Opera House

StageStruck - was developed with the assistance of the Federal Government's Australia on CD Program. StageStruck was designed for students to experience the world of the performing arts as well as showcasing the diversity of Australian Performers and Performing Arts Companies. StageStruck provides a highly interactive environment where students are able to explore each of the elements associated with designing and directing a performance whilst creating their own. Awards have been numerous and include: In 1998, EMMA Gold Award- best overall; BAFTA Interactive Treatment award in the United Kingdom. In 1999, New York Festivals International Interactive Multimedia competition - Gold Medal in the Education section; AIMIA Award - Best Arts/Cultural Title or Site and in 2000 it won the Milia d'Or Awards for the Education & Training Category

Exploring the Nardoo (1996). Client: Department of Land and Water Conservation, New South Wales

This is a program based on an inland water catchment, which can be investigated through four time zones and four locations in each time zone. Each time zone has a particular theme that transposes the four locations and each location will have an embedded investigation in the form of a scenario. Users can move readily from location to location in each time zone and from zone to zone. Students will be able to interrogate data and personalise results. The user investigation is supported by help facilities and guides as well as simulations and games designed to support solutions to problems. In 1? ? ? it won an EMMA Award (European Multi-Media Association) and one of best five new educational products for 1997 by the American Software Publishers Association.

Investigating Lake Iluka (1993). Collaborator: Apple Computer Australia

A simulated lake environment on CD ROM. Students can investigate various ecosystems of the lake, make physical, chemical and biological measurements, collect information about individual animal and plant species in and around the lake, and see and hear news reports, expert views and local opinions on a variety of issues relating to the lake and its ecology. Inquiry and problem-solving techniques have been embedded in the package through case studies of ecological scenarios presented to the user via media reports of problems posed directly to the user.

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